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**101. Ecology of Larval Fishes in Lake Oahe, South Dakota**

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By William R. Nelson

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# Ecology of Larval Fishes in Lake Oahe, South Dakota

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## Abstract

The time and location of spawning, food of larvae, and habitats used as nursery areas by young-of-the-year fishes were studied from 1972 to 1975 in South Dakota waters of Lake Oahe, a main stem Missouri River reservoir. Sampling locations were in the tributary rivers—the Grand, Moreau, and Cheyenne—and their embayments. The most heavily used spawning areas were in the rivers, which were the exclusive spawning ground for five fishes (goldeye, *Hiodon alosoides*; walleye, *Stizostedion vitreum*; sauger, *S. canadense*; white sucker, *Catostomus commersoni*; and minnows, *Hybognathus* sp.), and the major spawning ground of three others (white bass, *Morone chrysops*; buffalo, *Ictiobus* sp.; and carp, *Cyprinus carpio*). The upper reaches of the embayments were the preferred spawning locations of crappies (*Pomoxis* sp.) and the preferred nursery areas of most young fishes. The middle reaches of embayments were the least used areas sampled; no important species preferred them for spawning or nursery areas. The lower reaches were the primary spawning grounds of yellow perch (*Perca flavescens*), burbot (*Lota lota*), shiners (*Notropis* sp.), and darters (*Etheostoma* sp.). Year-class strength of river-spawning species was strongly correlated with river flow rates during the spawning season. Success of reservoir-spawning species was primarily dependent on above-average water levels, which inundated terrestrial vegetation to provide a substrate for egg deposition and cover for larvae. Neither availability of food nor competition for it appeared to be an important factor affecting year-class strength. Preserving adequate streamflow and enhancing reservoir shoreline areas by managing water levels, seeding vegetation, and eliminating grazing alongshore would probably ensure adequate reproduction of most species.

In reservoir environments, which are less stable than those of natural lakes, characteristics such as water level fluctuation, shoreline erosion, and sedimentation often have profound effects on fish reproduction. However, the reproductive success of a species can potentially be enhanced by managing the water levels. Before existing water management programs are altered, the spawning and nursery area requirements for the predominant species must be understood and the factors controlling year-class strength delineated.

This study was designed to determine the spawning season and habitat of the predominant reservoir species. I also investigated the influence of various physical and climatic factors and the availability of food on the annual abundance of larval fish. The importance of streamflows and reservoir water levels in providing spawning habitat and cover for young fishes was evident. Because adequate streamflows have occurred more commonly than above-average reservoir water levels, river-spawning rather than reservoir-spawning species dominate the fish populations of Lake Oahe.

## Description of Lake Oahe

Lake Oahe was formed in 1958 by the impoundment of the Missouri River near Pierre, South Dakota. The reservoir reached the base of flood control and multiple use (489.9 m above mean sea level) in late 1967. Among U.S. reservoirs, Lake Oahe ranks second in surface area (126,800 ha) and fourth in volume (23.7 billion $m^3$). It has a mean depth of 19.2 m, a length of 370 km, and a shoreline length of about 3,600 km (Fig. 1).

Filling of Lake Oahe inundated the valleys of the Cheyenne, Moreau, and Grand rivers to form large embayments. These rivers, which drain the prairie habitat of the western Dakotas, are highly turbid and an important source of the estimated 39.4 million $m^3$ of silt deposited annually in the reservoir (U.S. Army Corps of Engineers 1976). The Cheyenne River and embayment are considerably larger than the Moreau

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Fig. 1. Lake Oahe showing sampling stations in the Cheyenne, Moreau, and Grand rivers and embayments.

Table 1. *Monthly mean discharge ($m^3/s$) of the Cheyenne, Moreau, and Grand rivers into Lake Oahe, March-June, 1972-75.*[a]

| River and year | Month | | | |
|---|---|---|---|---|
| | March | April | May | June |
| **Cheyenne** | | | | |
| 1972 | 64.3 | 19.2 | 70.7 | 99.0 |
| 1973 | 39.7 | 43.7 | 52.3 | 35.6 |
| 1974 | 15.9 | 27.3 | 13.8 | 9.8 |
| 1975 | 14.5 | 76.7 | 83.6 | 31.9 |
| **Moreau** | | | | |
| 1972 | 110.7 | 3.4 | 43.4 | 8.6 |
| 1973 | 20.3 | 10.9 | 4.8 | 7.8 |
| 1974 | 1.7 | 2.6 | 0.7 | 0.7 |
| 1975 | 0.4 | 51.4 | 57.3 | 8.4 |
| **Grand** | | | | |
| 1972 | 83.5 | 13.7 | 38.2 | 16.3 |
| 1973 | 32.8 | 8.5 | 8.8 | 6.3 |
| 1974 | 6.4 | 17.1 | 4.2 | 3.2 |
| 1975 | 2.9 | 35.5 | 26.7 | 15.6 |

[a]Drainage areas ($km^2$) of the rivers: Cheyenne, 61,000; Moreau, 12,640; and Grand, 13,910. Annual mean and maximum flows ($m^3/s$) for different series of years: Cheyenne (1960-75), 24.3 and 1,240; Moreau (1954-75), 6.8 and 595; and Grand (1958-75), 6.8 and 425.

and Grand systems (Table 1). Spring runoff (March through June) in 1965-74 made up a large proportion of the annual flows: 72% for the Cheyenne River, 89% for the Moreau River, and 75% for the Grand River. Periods of no flow rarely occur in the Cheyenne and Grand rivers but are common in the Moreau River in fall and winter.

Flows from March through April in the Cheyenne, Moreau, and Grand rivers were above average in 1972 and 1975, about average in 1973, and below average in 1974 (U.S. Geological Survey 1972, 1973, 1974, 1975). This annual variation in runoff from 1972 to 1975 caused the water level of Lake Oahe to range in elevation between 485.8 and 491.8 m above mean sea level and the surface area to vary between 112,600 and 147,000 ha. Runoff in 1972 resulted in the water level rising from April through June, whereas the reduced volume of runoff in 1973 and 1974 resulted in low, declining water levels in these years (Fig. 2). Above normal spring runoff in 1975 resulted in rising water levels inundating 17,000 ha that had been exposed since the fall of 1972.

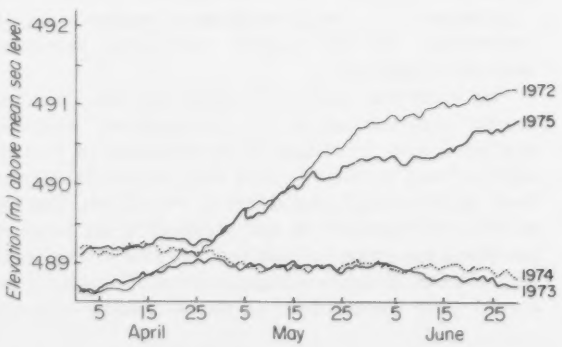


Fig. 2. Lake Oahe water levels from April through June, 1972-75.

Table 2. *Selected physical characteristics at embayment sampling stations.*

| Embayment and sampling station[a] | Distance to tributary river (km) | Maximum depth (m) | Mean temp (°C) | Mean Secchi disk reading (cm) |
|---|---|---|---|---|
| **Cheyenne** | | | | |
| Upper | 2 | 2 | 16.1 | 6.7 |
| Middle | 21 | 18 | 14.1 | 8.9 |
| Lower | 34 | 33 | 14.0 | 18.0 |
| **Moreau** | | | | |
| Upper | 2 | 1 | 15.9 | 5.3 |
| Middle | 13 | 6 | 15.7 | 5.4 |
| Lower | 19 | 18 | 14.2 | 12.9 |
| **Grand** | | | | |
| Upper | 2 | 1 | 16.9 | 4.5 |
| Middle | 11 | 5 | 15.3 | 5.8 |
| Lower | 19 | 14 | 14.3 | 11.2 |

[a]See Fig. 1 for locations of stations.

Extensive areas of terrestrial plants were inundated and killed by the high water levels in 1972. Plants failed to become established until late summer and fall along the shoreline during the lower water levels in 1973, but they spread over extensive areas of exposed shores in 1974. These plants were then inundated by the high water level in 1975. Bottom substrates in the Cheyenne embayment are predominantly clay and silty clay; shoreline vegetation was dominated by western wheatgrass (*Agropyron smithii*) and foxtail barley (*Hordeum jubaturm*). In the Moreau and Grand embayments the bottom substrates are clay and silt loam; curly leaf dock (*Rumex crispus*), fireweed (*Kothis scoparia*), and yellow sweet clover (*Melilotus officinalis*) were the dominant plant species that became established after the high 1972 water levels (Stanley and Hoffman 1975).

## Sampling Locations and Methods

Sampling stations were established in the Cheyenne, Moreau, and Grand rivers just upstream from the point at which they were influenced by the embayments, and the embayments were sampled in their upper, middle, and lower reaches (Fig. 1). From the uppermost to the lowermost sampling station in each embayment and from the uppermost (Grand) to the lowermost (Cheyenne) embayment, the water generally became progressively deeper, cooler, and clearer (Table 2). The Moreau River and embayment stations were sampled from 1972 to 1975 and the Cheyenne and Grand rivers and embayments in 1974 and 1975. Samples were taken at each station twice a week in 1972-73 and weekly in 1974-75, from April through June.

Eggs and larval fishes were collected with 0.5-m plankton nets (0.76 mm bar mesh). Embayment stations were sampled by towing the nets for 10 min at about 6 km/h. Paired tows were made at the surface along the shore, and at 3 m and at the surface offshore; if the water was too shallow for a tow at 3 m, two tows were made at the surface. River stations were sampled by suspending nets in the current for 10 min. Water temperatures were measured at each station with recording thermographs, placed 1 m below the surface.

Collections were preserved with buffered 5% formalin containing the dye Phloxine B; the dye facilitated separation of the eggs and larvae from detritus. Samples were sorted in the laboratory, eggs and larvae identified under magnifications of 10-80 X, and total lengths of fish measured. Larval fishes were identified from descriptions given by Fish (1932), Mansueti and Hardy (1967), May and Gasaway (1967), Nelson (1968), Siefert (1969), and Lippson and Moran (1974).

A current meter installed in the 0.5-m nets was used to determine the volume of water strained by the nets in 1973-75. The 1972 catch was converted by applying the average volumes of water strained in 1973-75 in the embayment tows (142 $m^3$) and river drift (61 $m^3$). This procedure should provide accurate estimates for the 1972 embayment samples, since all tows were made at the same speed and for the same length of time. Conversion of 1972 river samples was subject to error of undetermined magnitude, since the volume of water strained depended upon the flow rate.

Food of larvae was determined by enumerating the contents of the entire digestive tract. The composition and abundance of the zooplankton standing crop were

Table 3. *Percentage composition of catches of larval fish in 0.5-m plankton nets and of young of the year in 30.5-m bag seines and 10.7-m bottom trawls, 1972-75.*[a]

| Scientific name | Common name | Gear | | |
|---|---|---|---|---|
| | | Plankton net | Seine | Trawl |
| *Morone chrysops* | White bass | 27.2 | 33.6 | 56.6 |
| *Perca flavescens* | Yellow perch | 20.9 | 36.1 | 9.5 |
| *Ictiobus* sp. | | 17.4 | 5.6 | T |
| *I. cyprinellus* | Bigmouth buffalo | | 5.4 | |
| *I. bubalus* | Smallmouth buffalo | | 0.2 | |
| *Cyprinus carpio* | Carp | 7.6 | 0.3 | T |
| *Aplodinotus grunniens* | Freshwater drum | 6.5 | 1.0 | 18.7 |
| *Hiodon alosoides* | Goldeye | 2.3 | 1.1 | 1.0 |
| *Hybognathus* sp.[b] | Minnows | 1.1 | 4.0 | |
| *Stizostedion* sp. | | 0.5 | 0.6 | 3.4 |
| *S. v. vitreum* | Walleye | | 0.5 | 2.9 |
| *S. canadense* | Sauger | | 0.1 | 0.5 |
| *Pomoxis* sp. | | 0.5 | 1.0 | 6.4 |
| *P. annularis* | White crappie | | 0.8 | 4.6 |
| *P. nigromaculatus* | Black crappie | | 0.2 | 1.8 |
| *Etheostoma* sp. | | T | T | T |
| *E. nigrum* | Johnny darter | | T | T |
| *E. exile* | Iowa darter | | T | T |
| *Notropis* sp. | | T | 14.3 | 4.0 |
| *N. atherinoides* | Emerald shiner | | 12.6 | 0.1 |
| *N. hudsonius* | Spottail shiner | | 1.7 | 3.9 |
| *Catostomus commersoni* | White sucker | T | 0.9 | T |
| *Osmerus mordax* | Rainbow smelt | T | | 0.1 |
| *Lota lota* | Burbot | T | | |
| *Ictalurus punctatus* | Channel catfish | T | T | |

[a]T = trace (less than 0.05%).

[b]Includes the brassy minnow (*Hybognathus hankinsoni*) and silvery minnow (*H. nuchalis*), which were not separated in the collections.

estimated from catches in oblique tows made from the bottom to the surface with a Clarke-Bumpus plankton sampler equipped with a No. 20 nylon mesh net. Zooplankton and larval fish sampling was conducted concurrently. The degree of food electivity was determined by the method of Ivlev (1961). In this method, the proportion a food item makes up in the environment is compared with the proportion it makes up in the stomachs. The resulting index ranges from +1 when an item is present in the stomachs but not collected in the environment to −1 when an item is absent in the stomachs but present in the environment.

The abundance of young-of-the-year (YOY) fishes was estimated annually from 1965 to 1975 on the basis of a sampling program in which a 30.5-m bag seine was used during July and August and a 10.7-m bottom trawl during October. Samples were collected at various locations in Lake Oahe, in addition to the stations in the Cheyenne, Moreau, and Grand embayments. Descriptions of the methods used to obtain abundance indices were given by Beckman and Elrod (1971) for the seine and by Nelson and Boussu (1974) for the trawl.

## Catch Composition and Distribution

White bass and yellow perch dominated catches of larval and YOY fish (Table 3). Buffaloes and carp were well represented in larval fish catches but not in catches of YOY in seines or trawls. Larval freshwater drum were not caught until June, and YOY of this species were well represented only in trawl catches. Larvae of goldeyes, minnows, walleyes, and saugers were captured primarily in the Cheyenne, Moreau, and Grand rivers and larvae of crappies, darters, and shiners were primarily captured in the embayments. Larval white suckers and burbot were rarely captured; both species are uncommon in the reservoir. Adult rainbow smelt were introduced into the reservoir immediately upstream (Lake Sakakawea) in 1971, and are not known to have reproduced in Lake Oahe before

Table 4. *Mean catch of larval fish (number per 100 m³ of water strained) at each sampling station in the Cheyenne, Moreau, and Grand rivers and embayments, 1972-75.*

| | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| Station | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| River | 65 | 89 | 20 | 57 | 2 | 83 | 35 | 114 |
| Embayment | | | | | | | | |
| Upper | 14 | 64 | 54 | 7 | 33 | 76 | 33 | 119 |
| Middle | 2 | 19 | 25 | 4 | 10 | 13 | 10 | 19 |
| Lower | 18 | 15 | 83 | 5 | 7 | 9 | 3 | 18 |
| Annual mean | 25 | 47 | 45 | 18 | 13 | 45 | 20 | 67 |

1975. About 15% of the fish larvae captured were unidentifiable; most of these were catostomids and cyprinids captured at the three river stations.

Larval fish abundance was generally highest in the rivers or upper embayment stations and lowest in the lower embayment stations (Table 4). Large catches at the lower embayment stations in the Cheyenne embayment in 1974, and in the Moreau embayment in 1972 were exceptions. Annual mean catches were considerably higher in 1975 than in 1974. In the Moreau system catches were generally lowest in 1973 and highest in 1972 and 1975.

## Larvae of Major Species: Abundance, Spawning, Nursery Areas, and Diet

The relative abundance of eggs and larval fishes collected at the various sampling stations was used to estimate annual spawning success and the spawning time and location; principal nursery areas were deduced from relative abundance of YOY in seine catches.

### *White Bass*

The collections included more larvae of white bass than of any other species, primarily because these larvae were so numerous in 1975 (Table 5). They were also moderately abundant in 1972 in the Moreau embayment, but were scarce in all three embayments in 1973 and 1974. Larvae were scarce at the river stations; they were most abundant at the upper embayment stations, and progressively less abundant at the middle and lower embayment stations. Abundance declined progressively from the upper (Grand) to lower (Cheyenne) embayment.

Collection of white bass eggs and newly hatched larvae indicated that spawning began about 20 May and continued until about 22 June. Peak spawning was in early June when water temperatures were 15° to 17°C. Spawning habits in Lake Oahe were similar to those reported by Riggs (1955) for white bass in Indiana and Oklahoma reservoirs.

Distribution of eggs and larvae indicated that white bass spawned primarily in the lower reaches of the tributary rivers. Of almost 900 eggs collected in

Table 5. *Mean catch of white bass larvae (number per 100 m³) at each sampling station in the Cheyenne, Moreau, and Grand rivers and embayments, 1972-75.* (*T* < 0.5)

| | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| Station | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| River | T | 0 | 2 | 0 | 0 | 3 | 0 | 0 |
| Embayment | | | | | | | | |
| Upper | 3 | 48 | 21 | 1 | 3 | 76 | 10 | 77 |
| Middle | 2 | 13 | 7 | 1 | T | 8 | T | 5 |
| Lower | T | T | 1 | T | T | 4 | T | 4 |
| Annual mean | 1 | 15 | 8 | T | 1 | 23 | 3 | 24 |

Table 6. *Mean number of food organisms in stomachs of 261 larval white bass collected in the Moreau embayment in 1972 and 1975 and the Cheyenne and Grand embayments in 1975.*

| Length class (mm) | Number of stomachs | Number empty | Food organisms | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Copepods | | | Cladocerans | |
| | | | Rotifers | Nauplii | Cyclopoid | Calanoid | *Daphnia* | Others |
| 3.0-3.9 | 7 | 6[a] | | 1.0 | | | | |
| 4.0-4.9 | 19 | 10[a] | 0.2 | 0.9 | 0.2 | | | |
| 5.0-5.9 | 14 | | 0.8 | 0.7 | 0.7 | | | |
| 6.0-6.9 | 25 | 3 | 0.8 | 1.1 | 2.0 | 0.2 | | |
| 7.0-7.9 | 20 | 3 | 0.5 | 0.8 | 3.5 | 0.8 | 0.1 | |
| 8.0-8.9 | 29 | 1 | 0.1 | 0.5 | 2.9 | 1.0 | 0.2 | 0.1 |
| 9.0-9.9 | 16 | | 0.1 | 0.4 | 2.8 | 2.0 | | 0.1 |
| 10.0-10.9 | 18 | | 0.4 | 0.2 | 6.1 | 1.1 | | 0.6 |
| 11.0-11.9 | 18 | | 0.1 | 0.2 | 4.2 | 1.4 | 0.3 | 0.2 |
| 12.0-12.9 | 25 | | | | 4.2 | 3.1 | 0.5 | 0.3 |
| 13.0-13.9 | 21 | | 0.1 | | 2.7 | 3.3 | 0.5 | 0.5 |
| 14.0-14.9 | 12 | | | 0.1 | 6.7 | 4.6 | 0.7 | 0.7 |
| 15.0-15.9 | 37[b] | | | | 3.2 | 5.8 | 0.4 | 0.9 |

[a]Yolk present.
[b]The stomach of one larva in the 15.0- to 15.9-mm length class contained larvae of *Chaoborus*.

1974-75, 99% were collected at the river stations. Some spawning may have occurred in the vicinity of the middle and lower embayment stations; however, larvae captured there were generally large (> 8 mm), and had apparently migrated into the areas after hatching.

Seine catches of YOY white bass indicated that the upper reaches of embayments were the primary nursery areas: about 49% of the 13,400 fish caught in the three embayments in 1972-75 were collected at the upper stations, 31% at the middle, and 20% at the lower stations (excluded from consideration was the catch of 5,642 YOY white bass captured in a single seine haul at the lower Moreau embayment station in 1972).

Of 261 larval white bass stomachs examined, 16 contained only yolk material and 7 were empty (Table 6). Nauplii were an important first food and cyclopoid copepods were the primary food of larvae 6.0–12.9 mm long. Rotifers and cladocerans were never important in the diet, but calanoid copepods increased in importance as the fish increased in length. Ruelle (1971) reported that white bass 4–11 mm long first ate primarily nauplii and then cyclopoid and finally calanoid copepods, and that rotifers and cladocerans were rarely eaten.

White bass larvae initially selected copepod nauplii but the degree of selection declined rapidly (Fig. 3). Selection of cyclopoid nauplii increased rapidly, peaked when larvae were 5 mm long, and then gradually declined. Selection for calanoid copepods increased as length of fish increased.

### *Yellow Perch*

The yellow perch was the dominant forage fish in Lake Oahe and was the most abundant larval fish collected in 3 of the 4 years of sampling. Its abundance tended to increase from the upper to lower stations within an embayment (Table 7). Exceptions occurred

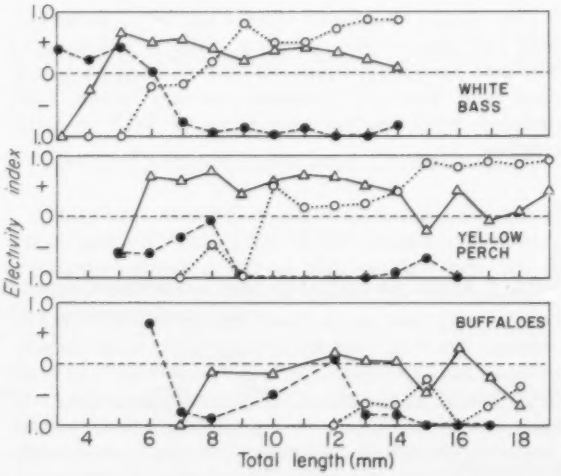


**Fig. 3. Electivity index (Ivlev 1961) of white bass, yellow perch, and buffaloes for nauplii (broken line), and cyclopoid (solid line) and calanoid (dotted line) copepods, Lake Oahe, 1975.**

Table 7. *Mean catch of yellow perch larvae (number per 100 m³) at each sampling station in the Cheyenne, Moreau, and Grand embayments, 1972-75.* ($T < 0.5$)

| | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| Station | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| Embayment | | | | | | | | |
| Upper | 1 | T | 1 | T | 10 | 2 | 9 | 7 |
| Middle | 3 | 3 | 5 | T | 8 | 1 | 9 | 12 |
| Lower | 11 | 14 | 89 | 7 | 8 | 7 | 2 | 12 |
| Annual mean | 5 | 6 | 32 | 3 | 8 | 3 | 7 | 10 |

in 1974, when catches were similar at all stations in the Moreau embayment, and were low at the lower station in the Grand embayment. No yellow perch were collected at river stations. Catches in the Cheyenne and Grand embayments increased from 1974 to 1975, whereas those in the Moreau embayment decreased; there the abundance was highest in 1972 and lowest in 1973.

The spawning habits of yellow perch are well known (see Thorpe 1977 for review). In Lake Oahe, eggs were observed deposited on inundated terrestrial vegetation such as wild plum (*Prunus americana*), buckbrush (*Symphoricarpos occidentalis*), or yellow sweet clover. Freshly deposited eggs were present on artificially placed brush piles from mid-April to early June, when water temperatures ranged from 8° to 13°C. Spawning peaked between early May in the shallow upstream embayments and late May in the deeper downstream locations; water temperatures were 10° to 12°C. The incubation period ranged from about 20 days for the eggs laid first to 10 days for those deposited late in the season.

Seine catches of YOY yellow perch in the embayments indicated that the lower reaches were the primary nursery areas. Of the nearly 5,700 perch captured, about 61% were collected in the lower reaches and 7% in the upper reaches.

Copepods were the primary food of yellow perch larvae (Table 8). Initial food items were nauplii, cyclopoid copepods, and a few rotifers. Calanoid copepods increased in importance as perch length increased to 8.0-10.9 mm; *Daphnia* sp. and other cladocerans did not make up a significant proportion of the diet until the perch were longer than 20 mm (not shown in Table 8). Only one stomach was empty.

Although copepod nauplii and rotifers were important food when perch larvae began feeding, nauplii were not eaten in proportion to their abundance (Fig. 3). Cyclopoid copepods were positively selected throughout most of the larval stage, and calanoid copepods after perch exceeded 10 mm in length. The food eaten was similar to that reported for perch larvae by Siefert (1972), except that Lake Oahe perch ate relatively fewer cladocerans.

Table 8. *Mean number of food organisms in stomachs of 244 larval yellow perch collected in the Moreau embayment in 1972 and 1975, and the Cheyenne and Grand embayments in 1975.* ($T < 0.05$)

| Length class (mm) | Number of stomachs | Food organisms | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Copepods | | | Cladocerans | |
| | | Rotifers | Nauplii | Cyclopoid | Calanoid | *Daphnia* | Others |
| 5.0-5.9 | 5 | 0.4 | 2.8 | | | 0.6 | |
| 6.0-6.9 | 29 | 0.3 | 4.0 | 2.8 | T | | |
| 7.0-7.9 | 36 | 0.8 | 2.1 | 3.7 | 0.9 | | |
| 8.0-8.9 | 24 | 0.2 | 1.8 | 3.5 | 1.9 | 0.1 | T |
| 9.0-9.9 | 13[a] | 0.7 | 0.4 | 4.7 | 1.8 | | 0.2 |
| 10.0-10.9 | 20 | 0.4 | 0.2 | 6.2 | 5.1 | | |
| 11.0-11.9 | 18 | 0.5 | | 8.7 | 1.3 | 0.1 | 0.1 |
| 12.0-12.9 | 23 | 0.1 | 0.1 | 6.7 | 3.2 | T | T |
| 13.0-13.9 | 13 | 0.1 | | 9.1 | 4.6 | 0.1 | 0.5 |
| 14.0-14.9 | 19 | | 0.1 | 8.0 | 4.3 | 0.6 | 0.2 |
| 15.0-15.9 | 44 | T | 0.2 | 6.9 | 7.9 | 0.4 | 0.2 |

[a]One stomach was empty.

Table 9. *Mean catch of buffalo larvae (number per 100 m³) at each sampling station in the Cheyenne, Moreau, and Grand rivers and embayments, 1972-75.* ($T < 0.5$)

| | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| Station | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| River | 7 | 49 | 1 | 1 | 0 | 65 | 24 | 960 |
| Embayment | | | | | | | | |
| Upper | 5 | 34 | T | 2 | 25 | 21 | 18 | 344 |
| Middle | T | 28 | 1 | 5 | 2 | 12 | 1 | 5 |
| Lower | 5 | 3 | 0 | T | 0 | 3 | 2 | 18 |
| Annual mean | 4 | 29 | T | 2 | 7 | 25 | 11 | 332 |

### *Bigmouth and Smallmouth Buffaloes*

Larvae of buffaloes could not be identified to species. However, most were probably bigmouth buffaloes, since more than 96% of the YOY buffaloes caught in seines were of this species.

The abundance of buffaloes was generally highest at the river stations and declined from the upper to the lower embayments (Table 9). Abundance also tended to decline from the uplake (Grand) to the downlake (Cheyenne) embayment. Estimated abundance was generally higher at the sampling stations in 1975 than in the preceding years. Of the 410 YOY bigmouth buffaloes collected in the embayments, 52% were collected at the upper, 30% at the middle, and 18% at the lower stations.

Bigmouth buffaloes were observed spawning in littoral areas and their eggs were found attached to inundated vegetation and detritus. No smallmouth buffaloes were seen in these spawning concentrations. Spawning was observed from early May until mid-June and peaked in late May and early June. The lowest water temperature when spawning was observed was 14.3°C, and peak spawning occurred at temperatures from about 16° to 18°C. These water temperatures are in general agreement with those reported by Canfield (1922) and Swingle (1954), except that Swingle reported that spawning still occurred at 26.7°C, whereas in Lake Oahe no spawning was observed after temperatures exceeded 24°C.

Rotifers, nauplii, and cyclopoid copepods were the foods initially consumed by larval buffaloes (Table 10). Rotifers (primarily *Keratella* sp. and *Branchionus* sp.) and nauplii were eaten by larvae of nearly all lengths examined, but calanoid copepods and cladocerans were important in the diet of fish 13 mm long or longer. Although rotifers, nauplii, and cyclopoid copepods were important diet items, they were seldom eaten in proportion to their abundance (Fig. 3); apparently buffalo larvae were nonselective feeders on all zooplankton of suitable size.

Table 10. *Mean number of food organisms in stomachs of 165 larval buffaloes collected in the Moreau embayment in 1972 and 1975, and the Cheyenne and Grand embayments in 1975.*

| Length class (mm) | Number of stomachs | Number with yolk | Number empty | Food organisms | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Copepods | | | Cladocerans | |
| | | | | Rotifers | Nauplii | Cyclopoid | Calanoid | *Daphnia* | Others |
| 5.0-5.9 | 2 | 2 | | | | | | | |
| 6.0-6.9 | 22 | 17 | | 1.6 | 3.0 | 2.8 | | | |
| 7.0-7.9 | 38 | 11 | 6 | 3.1 | 2.8 | 1.2 | 0.1 | | 0.1 |
| 8.0-8.9 | 16 | 2 | 2 | 1.2 | 4.3 | 1.8 | | | |
| 9.0-9.9 | 2 | | 1 | 11.0 | | | | | |
| 10.0-10.9 | 8 | 1 | | 1.4 | 7.9 | 6.3 | | 0.1 | 0.4 |
| 11.0-11.9 | 9 | | 3 | 4.5 | 4.3 | 16.5 | 0.7 | 0.3 | 0.5 |
| 12.0-12.9 | 11 | | 2 | 1.9 | 12.8 | 23.6 | | 1.1 | 1.3 |
| 13.0-13.9 | 14 | | 1 | 5.5 | 6.4 | 16.5 | 10.9 | 2.1 | 6.4 |
| 14.0-14.9 | 9 | | | 1.7 | 2.0 | 18.1 | 1.2 | 3.0 | 6.3 |
| 15.0-15.9 | 34 | | | 2.5 | 1.4 | 29.0 | 4.6 | 8.8 | 6.6 |

Table 11. *Mean catch of carp larvae (number per 100 m³) at each sampling station in the Cheyenne, Moreau, and Grand rivers and embayments, 1972-75.* ($T < 0.5$)

| | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| Station | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| River | 17 | 322 | 1 | 7 | 1 | 182 | 1 | 32 |
| Embayment | | | | | | | | |
| Upper | T | 2 | 1 | 13 | 1 | 55 | 2 | 36 |
| Middle | 0 | 10 | 3 | 3 | T | 29 | T | 7 |
| Lower | 1 | 2 | 1 | 1 | T | 7 | T | 6 |
| Annual mean | 5 | 84 | 2 | 6 | 1 | 68 | 1 | 20 |

### *Carp*

Carp were the fourth most abundant larvae in the collections, making up 7.6% of the total catch (Table 3). However, they constituted only about 0.3% of the catches of YOY in seines and less than 0.1% of the YOY caught in trawls in 1972-75 (Table 3).

Among the approximately 20 species of larvae collected, the carp was the only one caught at each of the stations sampled (Table 11). In general, catches tended to be largest at the river and upper embayment stations and smallest at the lower embayment stations. In general, catches were higher in 1975 than in 1974.

The spawning habits of carp are well known and easily observed. In Lake Oahe, spawning continued from mid-May through June; the peak was usually in early June. Water temperatures exceeded 15°C when spawning began and were 20° to 24°C during the peak.

The upper reaches of embayments were the primary nursery areas of YOY carp. Of the 117 carp seined in the three embayments, about 61% were captured at the upper, 36% at the middle, and 3% at the lower stations.

Stomachs of larval carp tended to contain less food than those of other species (Table 12) and more (25%) were empty. Rotifers predominated in the food of the smallest larvae that fed (6.0–7.9 mm long) but cyclopoid copepods were the major food item throughout the rest of the larval stage. Cladocerans (*Daphnia* sp. and *Bosmina* sp.) increased in importance as carp length increased.

### *Freshwater Drum*

Freshwater drum contributed 6.5% of the larval fish caught. Numbers in catches tended to decrease from the upper to the lower reaches of an embayment (Table 13). They were relatively abundant in the Moreau River in 1972 but none were caught in 1974 and few in 1973 or 1975; only eggs were collected in the Cheyenne and Grand rivers in 1974 and 1975. Freshwater drum were more numerous in 1975 than in 1974 in the Cheyenne and Moreau embayments; however, the peak catch in the Moreau embayment was made in 1972.

Freshwater drum had an extended spawning period; eggs were collected as early as 30 May (1974) and were still present each year in late June, when larval sampling was terminated. Water temperature was 15.6°C at the initiation of spawning and 20° to 24°C

Table 12. *Mean number of food organisms in stomachs of 233 larval carp collected in the Moreau embayment in 1972 and 1975, and in the Cheyenne and Grand embayments in 1975.*

| Length class (mm) | Number of stomachs | Number with yolk | Number empty | Food organisms | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Copepods | | Cladocerans | |
| | | | | Rotifers | Cyclopoid | Calanoid | *Daphnia* | Other |
| 5.0-5.9 | 7 | 7 | | | | | | |
| 6.0-6.9 | 58 | 19 | 8 | 0.8 | 0.4 | 0.1 | 0.1 | 0.5 |
| 7.0-7.9 | 117 | 3 | 42 | 1.3 | 1.1 | 0.1 | 0.4 | 0.7 |
| 8.0-8.9 | 28 | | 10 | 0.1 | 1.8 | 0.2 | 0.7 | 0.6 |
| 9.0-9.9 | 14 | | 2 | | 3.6 | | 0.3 | 0.2 |
| 10.0-10.9 | 4 | | | | 4.0 | | 1.0 | 1.0 |
| 11.0-11.9 | 1 | | | | 1.0 | | | |
| 12.0-12.9 | 4 | | | | 4.0 | | 5.2 | 1.8 |

Table 13. *Mean catch of freshwater drum larvae (number per 100 m³) at each sampling station in the Cheyenne, Moreau, and Grand rivers and embayments, 1972-75.* ($T < 0.5$)

| | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| Station | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| River | 0 | 0 | 14 | 3 | 0 | 8 | 0 | 0 |
| Embayment | | | | | | | | |
| Upper | 4 | 21 | 33 | 3 | 1 | 1 | 6 | 3 |
| Middle | T | 4 | 9 | 1 | 1 | 4 | 1 | 0 |
| Lower | 0 | 0 | 2 | 1 | T | 2 | T | 0 |
| Annual mean | 1 | 6 | 14 | 2 | 1 | 4 | 2 | 1 |

during the apparent peak, during the last 2 weeks in June.

Cyclopoid copepods were the main food of freshwater drum 4.0–11.9 mm long (Table 14) and were the only item positively selected. Cladocerans were present in most stomachs; *Daphnia* sp. increased in importance as fish length increased. Rotifers and nauplii contributed little to the diet.

### *Goldeye*

Goldeye larvae were most abundant in the rivers, and abundance declined from upper to lower embayment stations (Table 15). No larvae were collected at the middle stations in the Cheyenne and Grand embayments or the lower stations in any of the embayments. Larvae were considerably more abundant in 1975 than

Table 14. *Mean number of food organisms in stomachs of 128 larval freshwater drum collected in the Moreau embayments in 1972 and 1975, and the Cheyenne and Grand embayments in 1975* ($T < 0.05$)

| Length class (mm) | Number of stomachs | Number empty | Food organisms[a] | | | | |
|---|---|---|---|---|---|---|---|
| | | | Copepods | | | Cladocerans | |
| | | | Nauplii | Cyclopoid | Calanoid | *Daphnia* | Other |
| 4.0-4.9 | 13 | 2[b] | 0.1 | 1.1 | 0.6 | 0.2 | 0.3 |
| 5.0-5.9 | 24 | | T | 1.3 | 0.8 | 0.2 | 0.3 |
| 6.0-6.9 | 23 | 1 | | 2.1 | 0.4 | 0.2 | 0.3 |
| 7.0-7.9 | 21 | 1 | 0.1 | 2.2 | 0.4 | 0.2 | 0.2 |
| 8.0-8.9 | 17 | | | 3.2 | 0.9 | 0.4 | 0.2 |
| 9.0-9.9 | 12 | | | 2.8 | 0.9 | 0.7 | 0.6 |
| 10.0-10.9 | 12 | | | 6.8 | 1.0 | 1.5 | 0.3 |
| 11.0-11.9 | 6 | | | 4.8 | 0.2 | 1.8 | 1.2 |

[a]Stomachs of two fish 7.0-7.9 mm long each contained a rotifer.
[b]Yolk present.

Table 15. *Mean catch of goldeye larvae (number per 100 m³) at each sampling station in the Cheyenne, Moreau, and Grand rivers and embayments, 1972-75.* ($T < 0.5$)

| | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| Station | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| River | 2 | 11 | 4 | 7 | 0 | 8 | 4 | 4 |
| Embayment | | | | | | | | |
| Upper | 0 | 4 | 3 | 2 | 0 | 1 | 0 | T |
| Middle | 0 | 0 | 1 | T | 0 | T | 0 | 0 |
| Lower | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual mean | 1 | 4 | 2 | 2 | 0 | 2 | 1 | 1 |

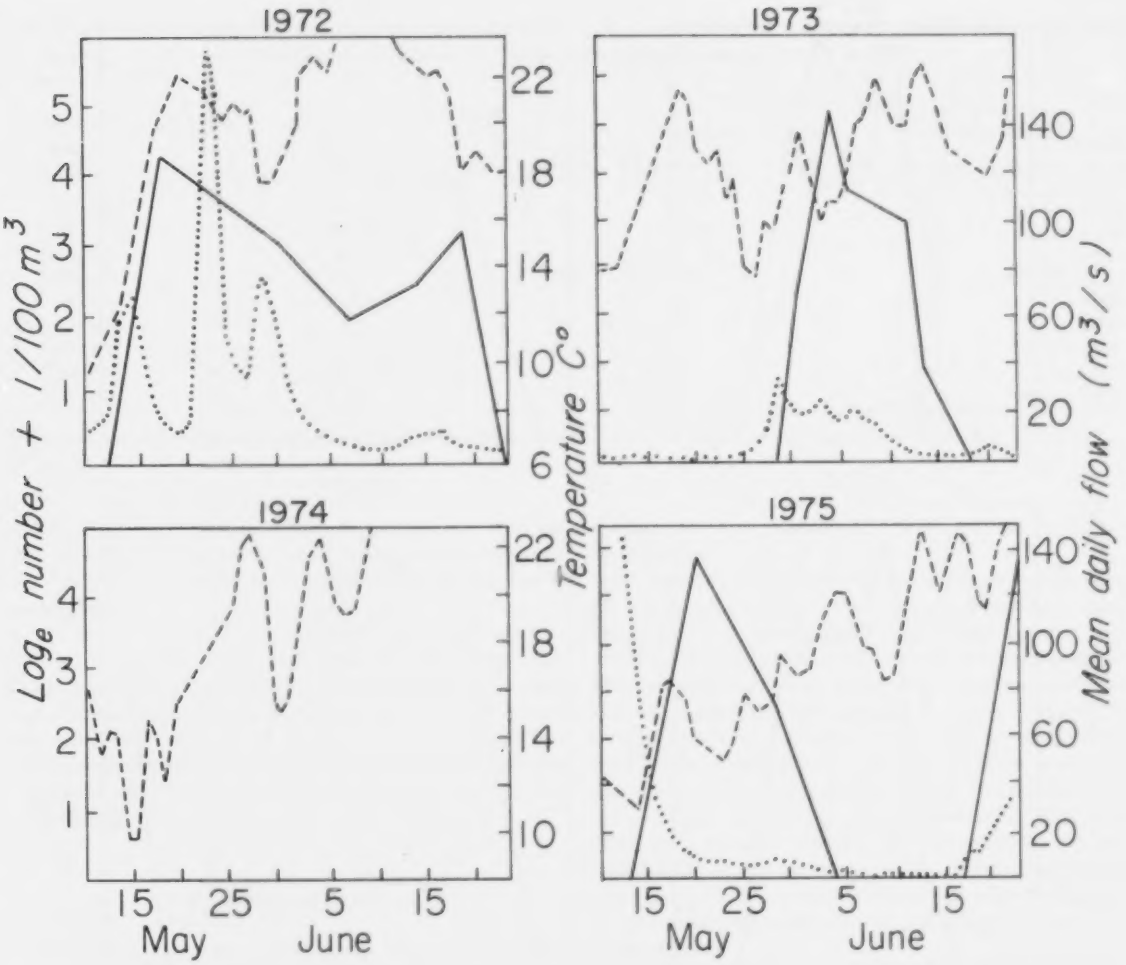


Fig. 4. Number of goldeye eggs per 100 m³ of water sampled (solid line), water temperature (broken line), and mean daily flow (dotted line) in the Moreau River. Water flow in 1974 (not shown) did not exceed 1.4 m³/s and no eggs were collected.

in 1974, when they were collected only at the Cheyenne and Grand river stations.

Goldeyes have semibuoyant eggs that are nonadhesive and large, about 4 mm in diameter (Battle and Sprules 1960). Kennedy and Sprules (1967) reported that goldeyes spawned in turbid rivers or backwater lakes and ponds of these rivers in Canada during May and June, when water temperatures were 10° to 13°C. In Lake Oahe, goldeyes spawned in the tributary rivers. In 4 years of sampling about 2,700 eggs were collected in the rivers and only 2 in the embayments. The maximum distance goldeyes migrate upstream from Lake Oahe before spawning is unknown. Goldeye eggs were present at the farthest upstream stations where samples have been collected—170 km in the Cheyenne River and 105 km in the Moreau River.

Goldeye eggs were collected from 18 May through 23 June (Figs. 4, 5). In 1973 and 1974 egg abundance was highest during the first 2 weeks of June, whereas in 1972 and 1975 there were two separate spawning periods, one in late May and another in late June. In the Moreau River in 1972, goldeyes spawned when water temperature increased from 11° to 19°C and river flow from about 15 to 70 m³/s (Fig. 4). The largest river flow recorded in this river in 1974 was 1.4 m³/s; no eggs were collected and spawning may not have occurred. In 1975 the Moreau River flow was high but decreasing, and spawning began as water temperatures

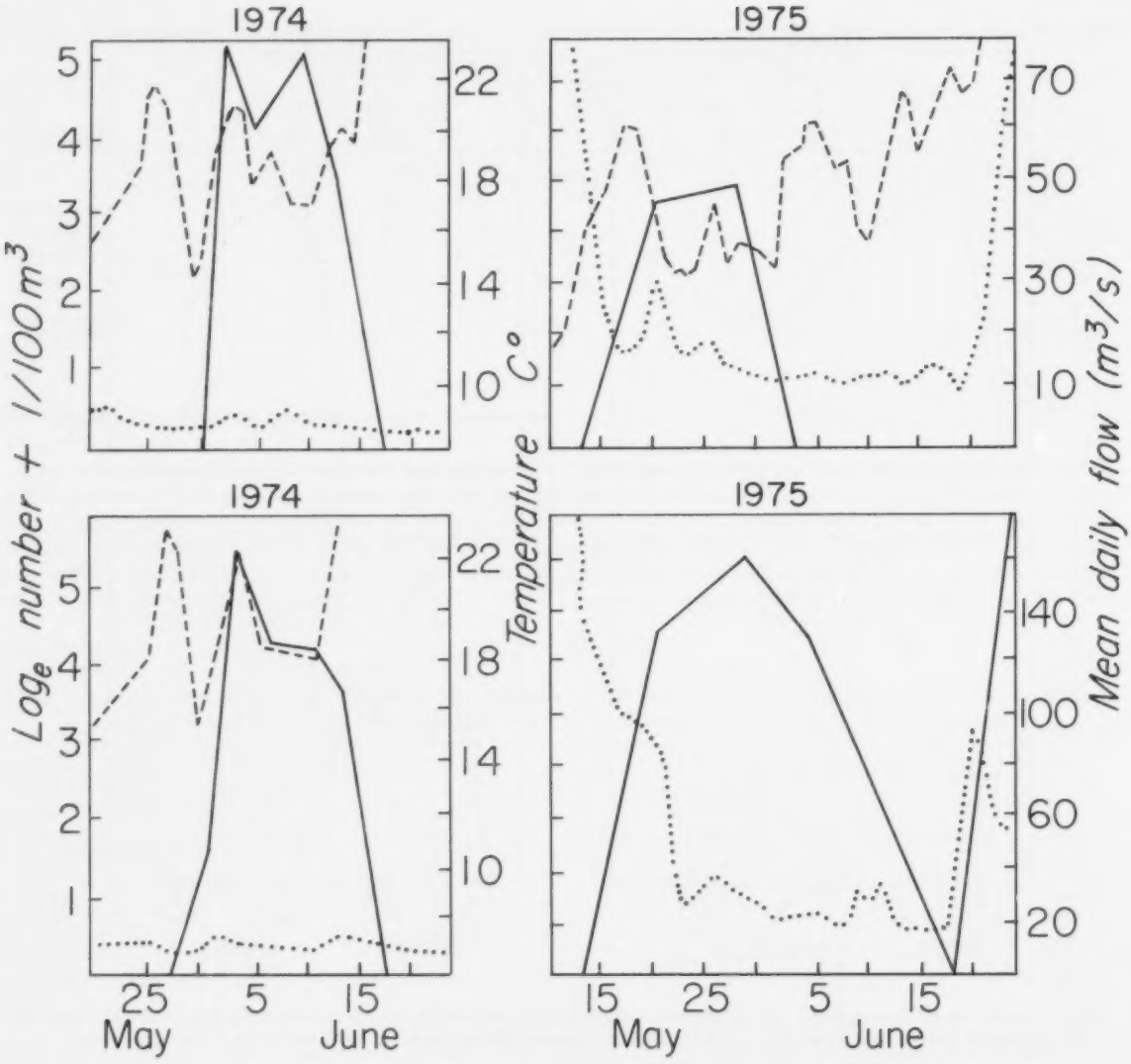


**Fig. 5.** Number of goldeye eggs per 100 m³ of water sampled (solid line), water temperature (broken line), and mean daily flow (dotted line) in the Grand (upper panel) and Cheyenne (lower panel) rivers, 1974-75. (Temperatures were not recorded in the Cheyenne River in 1975.)

increased from 12° to 16°C; a second spawning took place after 20 June, when river flows increased from 2 to 36 m³/s and water temperature exceeded 19°C.

Spawning in the Grand and Cheyenne rivers in 1974 began during the first week in June, when temperatures were increasing and the low river flows nearly doubled (Fig. 5). Conditions in 1975 were similar to those described in the Moreau River. Spawning began as temperatures increased and flows decreased, and recurred in the Cheyenne River when flows increased and water temperatures exceeded 19° C. Apparently a threshold temperature of about 12° C and adequate river flow were required before spawning began, and then as either temperature or flow increased, spawning occurred.

About 98% of the YOY goldeyes seined in Lake Oahe in 1972-75 were collected in the Cheyenne, Moreau, and Grand embayments, although only about

Table 16. *Mean number of food organisms in stomachs of 98 larval goldeyes collected in the Moreau embayment in 1972 and 1975, and the Cheyenne and Grand embayments in 1975.*

| Length class (mm) | Number of stomachs | Number with yolk | Food organisms | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Copepods | | | Cladocerans | | Insect larvae |
| | | | Rotifers | Nauplii | Cyclopoid | Calanoid | *Daphnia* | Others | |
| 9.0-11.9 | 19 | 19 | | | | | | | |
| 12.0-12.9 | 10 | 10 | | | | | 1.0 | | |
| 13.0-13.9 | 10 | 3 | | | | 0.1 | 1.2 | | |
| 14.0-14.9 | 13 | 6 | 0.1 | 0.3 | 0.3 | | 2.1 | 0.1 | |
| 15.0-15.9 | 4 | | | | | | 1.2 | | 0.2 |
| 16.0-16.9 | 14[a] | | | | 0.1 | 0.4 | 3.1 | 0.2 | 0.5 |
| 17.0-17.9 | 13 | | 0.2 | 0.2 | | | 3.0 | 0.1 | 0.6 |
| 18.0-18.9 | 8[b] | | 0.2 | | | 0.3 | 4.5 | | 0.8 |
| 19.0-19.9 | 7[a] | | 0.1 | | | | 3.4 | 1.4 | 0.6 |

[a]The stomach of one larvae contained an unidentified larval fish.
[b]Two stomachs were empty.

53% of the total fishing effort was expended in these embayments. Most (67%) of the goldeyes were caught in the upper reaches and fewest (1%) in the lower reaches.

Goldeye larvae fed primarily on *Daphnia* sp. (Table 16). Yolk was still present in some fish 14.0–14.9 mm long, although food was observed in fish as short as 12 mm long. Fish initially fed on *Daphnia* sp., and the average number eaten increased as the fish increased in length. The only other important food was insect larvae, of which chironomids made up 63% and chaoborids 10%.

### *Walleye and Sauger*

Walleye and sauger prolarvae (≤ 10 mm long) were separated on the basis of yolk sac shape (Nelson 1968), but postlarvae (10.0–19.9 mm long) were separated only to genus. About 70% of the larvae captured were identified to species; of those 93% were walleyes and 7% were saugers. The same percentages were found for YOY walleyes and saugers in bottom trawl catches; in seine catches 73% were walleyes and 27% were saugers.

In general, the abundance of walleyes and saugers decline progressively from river stations to the lower embayment stations (Table 17). These species were never collected at the lower Cheyenne embayment station and were captured in only 1 of 2 years at the lower Grand embayment station and in 2 of 4 years at the lower Moreau embayment station. In general, larvae were most abundant in the Grand River and least abundant in the Moreau River; in the Grand and Cheyenne rivers, abundance was considerably higher in 1975 than in 1974. Catches of YOY with seines indicated that walleyes were rather evenly distributed alongshore throughout the reservoir, whereas saugers tended to be more abundant in the upper reaches of the embayments.

Walleye eggs were collected in the Moreau River by agitating the rubble substrate and allowing dislodged eggs to drift downstream into the 0.5-m nets. Prolarval walleyes and saugers were collected only in the river and upper embayment stations. These observations indicate that the fish spawned in the tributary

**Table 17.** *Mean catch of* Stizostedion *sp. larvae (number per 100 m³) at each sampling station in the Cheyenne, Moreau, and Grand rivers and embayments, 1972-75.* ($T < 0.5$)

| Station | Cheyenne | | Moreau | | | | Grand | |
|---|---|---|---|---|---|---|---|---|
| | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 | 1974 | 1975 |
| River | 2 | 22 | 0 | 2 | 3 | 0 | 2 | 38 |
| Embayment | | | | | | | | |
| Upper | T | 6 | T | T | T | 0 | T | 6 |
| Middle | T | 2 | T | T | 0 | 0 | T | 1 |
| Lower | 0 | 0 | T | 0 | 0 | 2 | 0 | 1 |
| Annual mean | 1 | 7 | T | 1 | 1 | 1 | 1 | 11 |

Table 18. *Mean number of food organisms in stomachs of 49 larval* Stizostedion *sp. collected in the Moreau embayment in 1972 and 1975, and the Cheyenne and Grand embayments in 1975.*

| Length class (mm) | Number of stomachs | Number with yolk | Food organisms[a] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Copepods | | Cladocerans | | Chironomid larvae | Fish |
| | | | Cyclopoid | Calanoid | *Daphnia* | Others | | |
| 6.0-6.9 | | 17 | | | | | | |
| 7.0-7.9 | 2 | 17 | 1.5 | | | 0.5 | 1.0 | |
| 8.0-8.9 | 3 | 17 | 3.0 | | 0.3 | 0.7 | 1.3 | |
| 9.0-9.9 | 5 | | 2.8 | | | | 0.2 | |
| 10.0-10.9 | 5 | | 3.4 | | | 0.2 | | 0.2 |
| 11.0-11.9 | 2[b] | | | | | | | 1.0 |
| 12.0-12.9 | 2 | | 4.5 | 1.0 | 0.5 | | | |
| 14.0-14.9 | 1 | | | | 5.0 | 1.0 | | |
| 15.0-15.9 | 12 | | 3.1 | 0.3 | 1.2 | | 0.6 | 0.5 |

[a]Stomach of one fish 10.0-10.9 mm long contained two rotifers.
[b]One empty stomach.

streams rather than along the reservoir shoreline.

Prolarval walleyes and saugers were collected from the last week in April through the third week in May and postlarvae through mid-June. On the basis of time of capture, length of fish at capture, and estimated incubation period, spawning continued throughout April, and peaked near mid-month.

Cyclopoid copepods and chironomid larvae were the first food items consumed in significant amounts (Table 18). No nauplii were found in the relatively small sample of stomachs, and rotifers were present in only one. Cladocerans (primarily *Daphnia* sp.), but also *Bosmina* sp. and *Diaphanosoma* sp.) were commonly in the stomachs. Fish entered the diet when larvae attained lengths of 10.0 mm; all fish remains in stomachs were identified as carp.

### *Other Species*

Minnows were the seventh most abundant taxon collected (Table 3). Over 90% were caught at the river stations and less than 10% at embayment stations. The larvae were collected primarily during the last half of June.

Crappies were consistently collected in small numbers in the Moreau and Grand embayments; none were collected at river stations or in the Cheyenne embayment. About 80% of the crappies were collected from the upper embayment stations and the rest were nearly equally divided between the middle and lower stations.

Most of the few darters, shiners, and burbot collected were taken at the lower embayment stations. Darters and shiners were not collected until late June and burbot were usually collected in early May. Of these taxa, only shiners were common in the reservoir; I believe their poor representation in the catch was caused by the lateness of their spawning season (near the end of the sampling period).

White suckers were uncommon in the reservoir; catches of larvae were small and restricted to the tributary rivers.

Adult rainbow smelt were first observed in Lake Oahe in 1971, the same year they were introduced into upstream Lake Sakakawea; larval smelt were first collected in 1975. They were captured throughout the Moreau embayment, but were collected only at the middle station in the Cheyenne and Grand embayments. Largest catches were in early June and smaller catches continued throughout the month.

## Reproductive Success and First-year Survival

Various habitat, climatic, and biological factors directly and indirectly affect the spawning success and survival of the eggs and larvae of any particular species. Seven factors that may affect survival were investigated in the present study: (1) the area of land flooded on 1 April that either had never been flooded or had been exposed for 2 years to allow for revegetation; (2) the change in area of land flooded from 1 April to 30 June; (3) the annual abundance of predators (adult walleyes and saugers) estimated from trawl catches; (4) the annual abundance of forage fish (yellow perch and cyprinids except carp) estimated from seine catches; (5) the mean flow of the Cheyenne, Moreau, and Grand rivers during the spawning and incubation period of an individual species; (6) mean air temperature and wind velocity during the spawning and incubation period of an individual species; and (7) avail-

Table 19. *Correlation coefficients between some environmental characteristics and the average annual catch per haul of seven fish species during their first summer of life.*

| | 30.0-m seine | | | | 10.7-m trawl | | |
|---|---|---|---|---|---|---|---|
| Year | Bigmouth buffalo | Carp | White crappie | Black crappie | Goldeye | White bass | Freshwater drum |
| 1968 | 0.8 | 0.7 | 22.9 | 15.6 | 0.7 | 1.2 | 3.8 |
| 1969 | 2.7 | 2.5 | 0.9 | 3.3 | 0.5 | 29.5 | 18.4 |
| 1970 | 1.0 | 0.5 | 0.2 | 0.3 | 0.1 | 22.3 | 3.3 |
| 1971 | 0.8 | 2.4 | 0.2 | 0.9 | 2.9 | 13.1 | 14.0 |
| 1972 | 0.2 | 0.1 | 0.7 | 0.2 | 1.6 | 7.5 | 6.1 |
| 1973 | 3.0 | 0.2 | 0.2 | [a] | 1.2 | 34.5 | 31.3 |
| 1974 | 3.6 | 0.5 | 0.3 | 0.1 | 0.1 | 47.9 | 9.3 |
| 1975 | 9.6 | 0.7 | 1.1 | 0.6 | 0.5 | 107.3 | 18.4 |
| **Environmental characteristics** | | | | | | | |
| Newly flooded | 0.01 | 0.56 | 0.71[b] | 0.80[c] | 0.09 | -0.13 | -0.12 |
| Spring change | 0.18 | -0.16 | -0.50 | -0.54 | 0.12 | 0.27 | -0.17 |
| River flow | -0.33 | -0.11 | -0.17 | -0.23 | 0.83[c] | -0.29 | -0.25 |
| Abundance of predators | -0.77[b] | 0.21 | -0.10 | -0.06 | 0.05 | -0.68[b] | -0.49 |
| Forage fish | -0.25 | 0.19 | 0.89[c] | 0.95[c] | -0.22 | -0.38 | -0.37 |

[a]Less than 0.05 fish.
[b]$P < 0.05$.
[c]$P < 0.01$.

ability of food. These factors were correlated with the annual abundance of individual species as estimated from the average catch per seine or trawl haul since the reservoir attained operational pool level in 1968 (Table 19).

The area of newly flooded land controls the amount of vegetation available for egg deposition and cover for larval fish. The area of land flooded was significantly correlated with the abundance of black crappies and white crappies (Table 19). The change in amount of newly flooded land present during the spring was of little consequence for most species, but when it was relatively important, it had a negative effect. Nelson and Walburg (1977) reported that 79% of the fluctuation in abundance of YOY yellow perch in Lake Oahe (not included in the present analysis) was accounted for by the area of newly flooded land and change in flooded area. Gabel (1974) reported that when Lake Oahe was filling (1958-67), strong year classes of northern pike (*Esox lucius*), carp, and bigmouth and smallmouth buffaloes were established only in years when the water inundated terrestrial vegetation in the spring.

The abundance of predators and forage fishes may affect the strength of year classes by influencing the survival of YOY fish. Predator abundance was negatively correlated with the abundance of bigmouth buffalo and white bass (Table 19). The abundance of forage fishes was significantly correlated with the abundance of both species of crappies. However, this correlation may be spurious; it may indicate that spawning conditions optimal for crappies were also optimal for yellow perch (a main component of the forage species), rather than that forage species acted as a buffer to reduce predation.

The increases in river flow and larval fish abundance in the rivers from 1974 to 1975 (Tables 1, 4) illustrate the necessity of adequate flows to allow spawning fish to migrate from the reservoir into the rivers, to provide spawning habitat, and to return the eggs or larvae to the reservoir. The abundance of goldeyes, which spawn exclusively in the rivers, was significantly correlated with mean river flows (Table 19). Nelson and Walburg (1977) explained 55% of the variation in adult walleye year-class strength by mean river flows, changes in flows during the spring, and air temperature. Correlations of air temperatures and wind velocities with the abundance of other species were not significant.

The incidence of empty stomachs was low among the fish examined, except in carp and buffaloes. Of the 1,114 stomachs of all species examined, 135 contained only yolk, and 93 (9.5%) were empty. Stomachs were empty in less than 1% of the perch, 2% of the drum,

3% of the white bass, and 4% of the goldeyes, crappies, walleyes, and saugers. Empty stomachs were most prevalent in buffaloes and carp that had just absorbed their yolk sacs (Tables 10, 12). These species also made up a much lower percentage of the YOY than of the larval fish population, suggesting that their reproductive success was adequate but their survival poor.

To determine the foods for which larval fish could be competing, I combined the food ingested by all larvae into a single sample and computed the electivity index. This composite electivity index indicated that the smallest food items present (copepod nauplii and rotifers) and largest (*Daphnia* sp.) were the least selected prey (Fig. 6). As the season advanced and the fish grew larger, cyclopoid copepods were positively selected but decreasingly so, where selection for calanoid copepods tended to increase progressively. These relations occurred in all three embayments. *Bosmina* sp. was positively selected, to a generally declining degree, in the Grand and Moreau embayments, but was negatively selected in the Cheyenne embayment, where it was least abundant (estimated densities, in numbers per liter, were 0.14, 2.43, and 3.45 in the Cheyenne, Moreau, and Grand embayments, respectively).

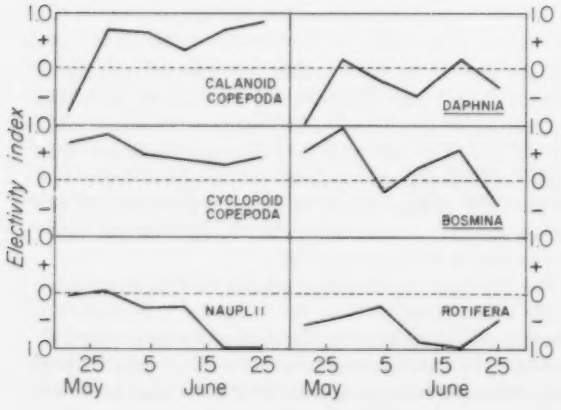


**Fig. 6.** Electivity index of the larval fish population (all species combined) for the predominant food items, Lake Oahe, 1975.

Rotifers, nauplii, cyclopoid copepods, and *Bosmina* sp. were the primary foods of larval carp and buffalo. When the mean number of these organisms consumed at the upper stations in the embayments in 1975 was calculated by multiplying the average number of organisms consumed by the abundance of the taxa (Table 20), it appeared that zooplankton standing crops should be sufficient to support this density of fish larvae, even though some juvenile and adult fishes provide additional competition. Consequently, the relatively high incidence of empty stomachs observed in larval carp and buffaloes did not appear to be caused by a lack of available food or competition for it.

## Management Implications

The enhanced reproductive success of northern pike, carp, bigmouth buffalo, smallmouth buffalo, and yellow perch in Missouri River reservoirs when terrestrial vegetation was flooded has been well documented (Walburg and Nelson 1966; Gasaway 1970; Gabel 1974; Moen 1974; June 1976; Nelson and Walburg 1977). These effects were particularly evident when the reservoirs were being filled and the prairie grasses were first inundated. Since Lake Oahe attained full capacity in 1968, these conditions have only been approximated when above-normal water levels during the April–June spawning period followed below-normal levels that had allowed shoreline vegetation to become reestablished. This pattern of water level fluctuation occurred in Lake Oahe in 1973–75. Water levels were more than 2 m lower in 1973 than in the previous year; shoreline vegetation was nonexistent during spring, and in the Moreau embayment the average number of larvae collected was about 5/100 m³. Conditions were similar in 1974, but some vegetation that had become established during late summer and fall 1973 was flooded, and average larval fish catches increased to 17/100 m³. In 1975, when high water inundated relatively dense stands of vegetation that had become established in the previous 2 years, the average catch of larvae increased to 33/100 m³. The average larval fish catch from 1974 to 1975 increased from 11 to 33 per 100 m³ in the Cheyenne embayment and from 15 to 52 per 100 m³ in the Grand embayment.

The importance of tributary streams for spawning of Missouri River reservoir fishes has not been fully appreciated. Superficially, because of the high turbidity and erratic flows, these rivers do not appear to provide favorable spawning habitat. However, spring flows are commonly adequate to keep soil particles in suspension, scour the bottom to provide suitable substrates, and transport the eggs or larvae to the reservoir. Reproduction of important species such as walleyes, saugers, and goldeyes were dependent on adequate streamflows. The greater frequency of adequate streamflows than of high reservoir water levels has caused a shift in the Lake Oahe fish population from reservoir to river spawners (Fig. 7). As the reservoir filled from 1965 to 1968, about 95% of the YOY fishes caught at the end of their first summer were species produced in the reservoir. After Lake Oahe reached capacity, the proportion of YOY fish produced in the

Table 20. *Amount of food available and consumed by larval carp, buffaloes, and all other fishes, by weekly sampling series, at the upper stations in the Cheyenne, Moreau, and Grand embayments, 1975.*

| Taxa of plankton available and eaten by different fishes | Sampling date | | | | |
|---|---|---|---|---|---|
| | | June | | | |
| | May 28 | 4 | 11 | 18 | 25 |
| **Available** (No./m³) | | | | | |
| Rotifers | 134,300 | 94,010 | 25,760 | 20,160 | 7,240 |
| Copepods | | | | | |
| Nauplii | 25,750 | 26,150 | 80,350 | 101,690 | 43,310 |
| Cyclopoid | 6,910 | 18,880 | 43,060 | 64,780 | 29,930 |
| *Bosmina* | 70 | 1,370 | 7,290 | 4,590 | 2,520 |
| **Eaten** (No./100 m³) | | | | | |
| *Carp* | | | | | |
| Rotifers | 32.26 | 4.45 | 0.91 | 0 | 0 |
| Copepods | | | | | |
| Nauplii | 0 | 0 | 0 | 0 | 0 |
| Cyclopoid | 1.24 | 1.55 | 0.27 | 0.15 | 2.46 |
| *Bosmina* | 2.93 | 1.20 | 1.01 | 0.16 | 1.38 |
| *Buffaloes* | | | | | |
| Rotifers | 2.81 | 33.67 | 11.53 | 0 | 5.06 |
| Copepods | | | | | |
| Nauplii | 0.42 | 9.00 | 942.65 | 0 | 0.34 |
| Cyclopoid | 0 | 0.23 | 6.10 | 181.58 | 29.76 |
| *Bosmina* | 0 | 0 | 229.14 | 81.43 | 6.83 |
| *Other fishes* | | | | | |
| Rotifers | 2.82 | 16.72 | 11.50 | 0 | 7.80 |
| Copepods | | | | | |
| Nauplii | 13.50 | 7.86 | 34.49 | 3.91 | 2.79 |
| Cyclopoid | 34.49 | 48.19 | 761.37 | 156.84 | 344.20 |
| *Bosmina* | 0 | 0 | 0.72 | 1.61 | 0.17 |

reservoir steadily declined and was less than 30% in 1974 and 1975.

Because most fish reproduction occurs in the tributary rivers and the upper reaches of embayments, the protection and enhancement of these areas should receive attention. Instream flow requirements should be established for the tributaries, and the placement of water intake structures in the tributaries or upper reaches of embayments that might entrain or impinge fish eggs or larvae should be discouraged. The rate of revegetation of shorelines could be increased by excluding cattle from the upper reaches of embayments to eliminate the detrimental effect of grazing, and by seeding newly exposed shorelines with fast-growing or better adapted plant species.

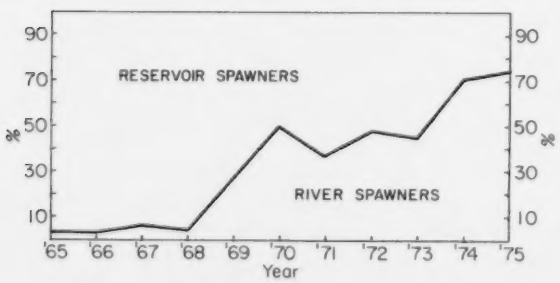


**Fig. 7. Percent composition of young-of-the-year fishes spawned in the reservoir and in tributary rivers of Lake Oahe captured with 10.3-m bottom trawls, 1965-75.**

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